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Improving Centrifugal Cleaner Efficiency Through Temperature Mismatching

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Abstract

Stickies have a higher coefficient of thermal expansion than does water, and their specific gravity changes with temperature. If a pair of identical cleaners is operated at two different temperatures, then the stickie will have a different specific gravity in each cleaner, and its likelihood of rejection will increase. Three pilot trials were run, and cleaning efficiency improved significantly when two cleaners were run at a temperature difference of 10°F. In general, cleaning efficiency was much poorer for a mixture of stickies than for a single stickie. This is attributed to reagglomeration; two stickies can combine to form mixtures of varying specific gravity, many of which will be of near-neutral buoyancy. This implies that cleaners will function best with relatively clean stock containing only a few different types of stickies.

Introduction

Since stickies are organic compounds, their coefficients of thermal expansion are usually higher than that of water (1). Hence, when a stickie/water suspension is heated, the stickie will expand to a greater degree, and its specific gravity will decrease. Consider a situation where a pair of identical centrifugal cleaners is operated at two different temperatures. A stickie of specific gravity of one in the first cleaner will not be rejected. However, it will have a different specific gravity in the other cleaner, and the probability of its removal in the second cleaner will increase. Hence "temperature mismatching" should increase cleaner efficiency (2). In this paper, we validate the concept through three pilot trials run at Beloit Corporation's Pittsfield, MA, facility.

Experimental

Stickie suspensions were prepared by spreading the material on copy paper, and blending it with water at 140°F for 10 minutes. Disintegration of the stickie alone leads to rapid reagglomeration. The fiber present interrupts the collision frequency of the stickie particles and inhibits recombination (3). The suspension was then added to 10 lbs of bleached hardwood virgin kraft stock at 0.8-0.9% consistency, and stirred for 10 minutes to insure uniform mixing. The stickies were pumped through either a sequence of a forward (POSIFLOW) and reverse (UNIFLOW) cleaner (trial 1), or through reverse cleaners (trials 2 and 3). For the first two trials, handsheets prepared from the several fractions were analyzed either manually at IPST, or through image analysis at Beloit. For the third trial, a Pullmac 0.004″ screen was used to isolate the stickies.

Results and Discussion

Trial 1

The stickies used comprised two EVA glue sticks of ρ=1.01 at room temperature, and two sticks (impregnated with metal specks) of overall ρ=1.4. The system was brought to 120°F and the entire stock was pumped through a POSIFLOW and a UNIFLOW cleaner in series. The rejects were discarded, and ten handsheets were prepared from furnish taken from the feed and accepts streams. These handsheets are called the <u>120F</u> samples. The stock was then recirculated through the cleaners; handsheets prepared from the feed and accepts are called the <u>120F/120F</u> samples. The rejects were returned to the stock, so that the stock was equivalent to the accepts from the first pass through the cleaners. The temperature was then raised to 130°F, the stock was pumped through the cleaners, and the feed and accepts were again sampled. The resulting handsheets are termed the <u>120F/130F</u> samples. Hence, the <u>120F/120F</u> samples refer to material passed through two sets of cleaners kept at 120°F, while the <u>120F/130F</u> samples reflect stock cleaned sequentially at 120 and 130°F. Comparison of the stickie counts in the <u>120F/120F</u> and <u>120F/130F</u> accepts should reveal whether or not the temperature difference improves cleaning efficiency.

To establish counting accuracy, the counts in the POSIFLOW accepts were compared to the UNIFLOW feed for each run; they should be equal, since the UNIFLOW follows the POSIFLOW, and the samples should be equivalent. The results shown in Figure 1 for stickies of all sizes (0.002-5 mm^2), and in Figure 2 for a larger subset (> 0.04 mm), demonstrate this to be the case; the average deviation is 8%. Results of image-analysis of five handsheets are listed in Table 1; those from manual counting of all ten UNIFLOW handsheets for stickies > 1 mm are provided in Table 2. Almost all of these large stickies contained metallic specks from the higher-density glue stick.

The cleaning efficiency is quite low, not because of any shortcomings of the cleaners (which have an acceptance window of at least ρ=0.985-1.015), but because most of the stickies fall into this window. Since we are using mixtures of materials of different specific gravities, reagglomeration will occur. We have recently shown (4) in mill trials that stickies reagglomerate quite soon after the repulper, and that pure (i.e., single-component) stickies are rarely found downstream in mills that use a complex furnish. When two stickies of different specific gravities reagglomerate, they can form mixtures with a range of specific gravities, many of which will be of near-neutral buoyancy and will be transparent to the cleaners.

Image analysis results from the second set of cleaners are presented in Figures 3-5. Consider the Figure 3 results, which reflect all stickies, regardless of size. The <u>120F/120F</u> and the <u>120F/130F</u> stickies counts are essentially the same, indicating that temperature mismatching does not improve cleaning efficiency. However, it is evident from Table 1 that most of the stickies are small, and it is known that cleaning efficiency is low for stickies smaller than about 0.2 mm^2 (5). Hence, an improvement is not expected for small stickies.

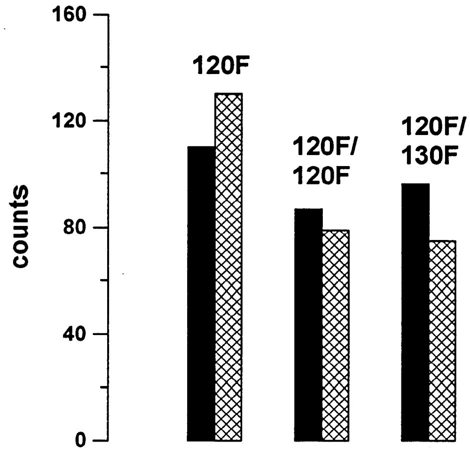


Figure 1: POSIFLOW accepts (black) and UNIFLOW feed (hatched) for all stickies.

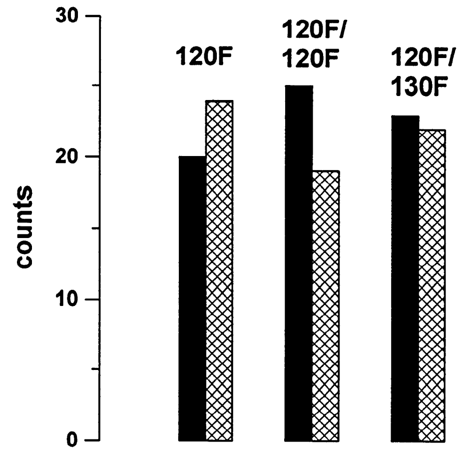


Figure 2: POSIFLOW accepts (black) and UNIFLOW feed (hatched) for stickies > 0.04 mm

Table 1: Results from image analysis

	POSIFLOW (feed/accepts)		UNIFLOW (feed/accepts)	
	all	>0.04 mm^2	all	>0.04 mm^2
120F	146/110	40/20	130/114	24/27
120F/120F	86/87	17/25	79/88	19/21
120F/130F	70/96	9/23	75/76	22/11

Table 2: Results from manual analysis of UNIFLOW handsheets for stickies > 1 mm.

	IPST (> 1 mm)[1]	average
120F feed	19, 25	22
120F accepts	14, 19	17
120F/120F feed	19, 18	19
120F/120F accepts	14, 14	14
120F/130F feed	21, 17	19
120F/130F accepts	8, 10	9

[1]averaged from two independent analyses

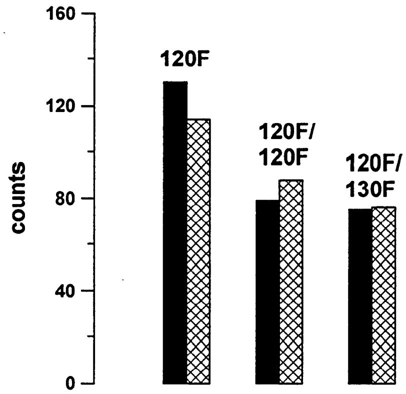


Figure 3: UNIFLOW feed (black) and accepts (hatched) for all stickies (image analysis).

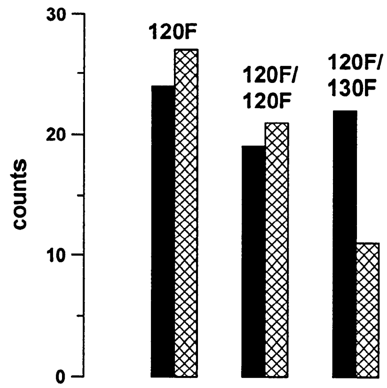


Figure 4: UNIFLOW feed (black) and accepts (hatched) for stickies > 0.04 mm. (image analysis).

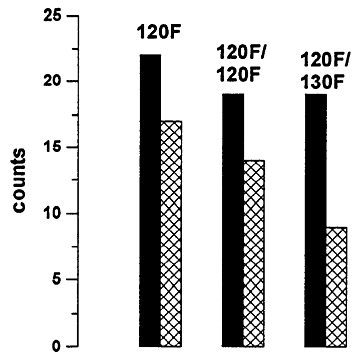


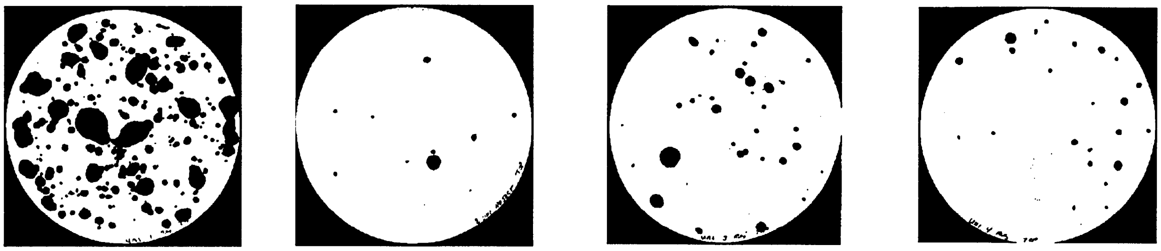
Figure 5: UNIFLOW feed (black) and accepts (hatched) for stickies > 0.1 mm. (manual counts).

For the larger stickies, the reduction in counts from the 120F feed to the 120F/120F accepts is barely outside the average uncertainty of 8%, but the corresponding reduction to the 120F/130F accepts is much larger at 54%. Similar results are seen for the manual counts in Figure 5, where the corresponding reductions are 23, and 59%, respectively. Hence, these results suggest that temperature mismatching increases cleaner efficiency for the larger stickies.

Trial 2

A different stickie (hot-melt glue stick, Black and Decker 2 Temp) of specific gravity close to one at the experimental temperature was chosen for this trial. The specific gravity at the experimental temperature was determined as follows. A glue stick was added to cold water whereupon it sank. The water was then slowly heated and the transition temperature at which the stickie floated and its specific gravity was one was 15°C. The values in Table 3 were calculated assuming that the coefficient of thermal expansion of the stickie was three times that of water. This value has been determined for PVAc (1).

Table 3: Specific gravity of the hot melt at different temperatures (6)			
temp (°C)	temp (°F)	density of water[1]	specific gr of stickie
40	104	0.9922	0.986
50	122	0.98804	0.978
60	140	0.9832	0.968



92F **92F/92F** **92F/119F** **92F/129F**

Figure 6: Stickies in handsheets prepared from the rejects stream

Four glue sticks were homogenized and added to stock, which was pumped twice through a reverse cleaner at 92°F. It was then heated stagewise to 119 and 129°F, and a portion was cleaned at each temperature. The accepts and rejects streams were sampled during each pass. Hence, the stock experienced reverse cleaning at 92F, 92F/92F, 92F/119F, and 92F/129F. In contrast to the first trial where the cleaning efficiency was poor, excellent cleaning was now obtained. This reinforces the argument proposed above, that the cleaning efficiency for a single stickie will be much higher than that for a mixture, since the system will be challenged with a contaminant of a single specific gravity instead of a wide range thereof. The amount of stickie carried through to the accepts was too small to allow a meaningful statistical evaluation to be made. Nevertheless, the benefit of temperature mismatching could be estimated from the handsheets made from the rejects stream shown in Figure 6. The **92F** handsheet is the most contaminated, demonstrating that most of the stickies are removed in the first pass. A small amount of carryover material is present in the **92F/92F** handsheet. The **92F/119F** and the **92F/129F** handsheets contain more stickies than does the **92F/92F** handsheet, indicating that temperature mismatching increases removal efficiency. The stickies in the **92F/129F** handsheet are smaller than those in the others, probably because the higher temperature breaks them up into smaller particles.

Trial 3

Since temperature mismatching seemed to be most effective for the larger stickies, a 0.004″ Pulmac screen, which would only isolate the larger stickies was used in the third trial. Also, the cleaners were run in 5°F increments to establish the minimum temperature required for an improvement in efficiency. The stickies used comprised four EVA glue sticks (10 g) and 10g of cured Carbotac (an acrylate latex from B.F. Goodrich). The stock (with the stickies) was warmed to 110°F, and passed through a UNIFLOW cleaner in the following sequence.

1. The entire stock at 110°F was cleaned with a UNIFLOW cleaner; the handsheets sampled are called the **110F** sample.
2. A portion of the stock was re-cleaned through the UNIFLOW at 110°F. The associated **110F/110F** handsheets represent sequential cleaning at 110°F.
3. The stock was warmed to 115°F and a portion cleaned through the UNIFLOW. The resulting **110F/115F** handsheets correspond to sequential cleaning at 110 and 115°F.
4. The stock was then warmed to 120°F and the entire stock passed through the UNIFLOW. The **110F/120F** handsheets symbolize sequential cleaning at 110 and 120°F.
5. The stock was warmed to 125°F and a portion cleaned through the UNIFLOW. Since the entire stock was cleaned in the preceding step, the **120F/125F** handsheets prepared represent sequential cleaning at 120 and 125°F.
6. The stock was warmed to 130°F and a portion cleaned through UNIFLOW. Handsheets prepared from these **120F/130F** samples result from sequential cleaning at 120 and 130°F.

As in the first trial, the cleaning efficiency was quite poor, probably because a mixture of stickies was used. The data provided in Table 4 and Figure 7 show that the feed:accepts ratio of the **110F**, **110F/110F**, and **110F/115F** samples are similar. However, a clear improvement was realized for the **110F/120F** sample. No significant change is seen for the **120F/125F** measurement, but a dramatic improvement is observed at **120F/130F**. It seems that an increase of 5°F is inadequate, but that a 10°F temperature difference improves cleaner efficiency quite dramatically.

Table 4: Pulmac analysis of stickies (sq mm/kg)

sample	feed	accepts	percent reduction
110F	3,785	2,230	41
110F/110F	3,850	2,300	40
110F/115F	2,670	1,620	39
110F/120F	7,715	1,800	77
120F/125F	4,280	4,165	3
120F/130F	1,655	90	95

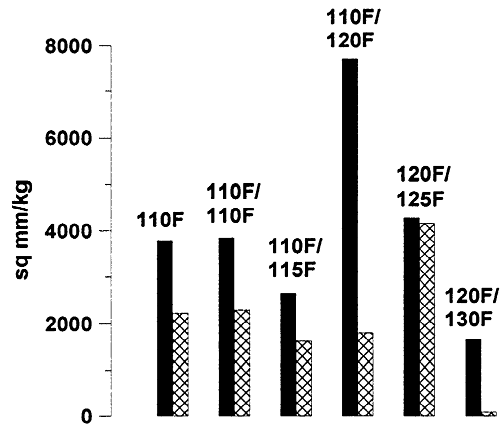


Figure 7: Pulmac analysis of stickies (black: feed, hatched: accepts)

Summary

The overall cleaning efficiency was poor for the first and third trials where two stickies were used, but was excellent for the second where only a single stickie was present. The specific gravities of the polymers were similar (except for the material containing the metal specks used in the first trial), and the large difference in performance cannot be due to differences in specific gravity. Rather, as discussed above, the potential for forming mixtures with a range of specific gravity exists if the stickies reagglomerate, in which case, cleaning efficiency will decrease as the number of types of stickies in the system increases. Cleaner specifications are usually defined with pure contaminants, and design efficiencies may not be met in the field if a wide variety of contaminants are encountered. Cleaners will work best when faced with a relatively clean furnish containing only a few types of stickies.

Temperature-mismatching cleaners improved removal of the larger stickies if a 10°F difference was applied. A smaller difference is less effective; a larger one may break down the stickie into smaller particles, which is detrimental. The cost of implementing the temperature difference will depend on whether or not waste steam is available. One newsprint mill estimates the cost to be of the order of 1¢/ton/°F (7). The feasibility will also depend on whether or not the temperature change can be tolerated in the process.

There is a perception in industry that screens work better than cleaners. Operationally, this may well be correct, since some mills that have cleaners installed no longer choose to run them. The physics of cleaning is more complex than that of screening, and our understanding of the cleaning mechanism is incomplete. As a result, cleaner performance can be unpredictable. There is, however, a good reason for continuing to clean. Screens have an inherent limitation: small particles that go through them can later agglomerate to form larger particles. Cleaning offers a different dimension, and a combination of screens and cleaners should lead to better decontamination than would screens alone. While screens will probably remain the first line of defense, cleaners have a place in at least those recycle operations that require the highest product quality. Since temperature mismatching appears to be effective, it could be useful in mills where cleaners are already installed, and where low-grade steam is available.

Acknowledgment

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